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Air Quality and Energy Conservation Benefits from Using Emulsions to Replace Asphalt Cutbacks in Certain Paving Operations

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This paper reviews practices found in the use of liquified asphalts for paving purposes. It examines (1) the solvent content difference in asphalts liquified with petroleum distillates (cutback asphalts) and asphalts liquified using water and an emulsifying agent, and (2) the amounts of hydrocarbons emitted when using cutback asphalts in relation to national and state hydrocarbon emissions. The substitutability of cutbacks and emulsions are discussed. Energy conservation considerations are treated. The results of an eight-state telephone survey of highway paving practices are presented.

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AIR QUALITY AND ENERGY CONSERVATION BENEFITS FROM USING EMULSIONS TO REPLACE ASPHALT CUTBACKS IN CERTAIN PAVING OPERATIONS

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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January 1978

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Executive Summary

This paper examines the air quality and energy conservation aspects of asphalt paving practices using liquefied asphalt. There are two basic types of liquefied asphalt: (1) asphalts liquefied with petroleum distillates such as kerosene or heavy naphtha, called cutback asphalts, and (2) asphalts liquefied using water and an emulsifying agent, called emulsified asphalts. One type of emulsified asphalt (cationic) is cured through an electrochemical process. All other types of liquefied asphalt are cured through the evaporation of the liquefying constituent. Cutbacks emit reactive hydrocarbons during the curing process; emulsions emit almost no air pollutants.

In 1975 cutbacks accounted for 2.3% of estimated national hydrocarbon emissions. In some states the cutbacks accounted for more than 15% of the state's estimated total hydrocarbon emissions. Some states, e.g., Wisconsin, Indiana, Illinois, Ohio, Pennsylvania, Virginia, and West Virginia, have significant air stagnation problems and require regulatory control of hydrocarbon emissions to attain and maintain oxidant air quality standards. These states also have had significant hydrocarbon emissions attributable to paving with cutbacks. Since asphalt paving operations occur predominantly during warm-weather months, when formation of oxidants from photochemical synthesis of hydrocarbon emissions is most prevalent, the decreased use of cutback asphalt could provide major assistance in oxidant attainment and maintenance strategies.

It is estimated that in 1975 more than 10 million barrels of petroleum distillates were used nationally to liquefy asphalt for paving purposes. These distillates represent fuels which were evaporated to the atmosphere or were retained in the pavement. The total energy associated with laying one gallon of cutback asphalt as pavement is about 50,200 Btu, while the total energy associated with a gallon of emulsified asphalt is about 2,830 Btu. For these reasons, the use of emulsified asphalt as a replacement for asphalt cutback has energy benefits.

Some paving operators claim three instances when emulsions cannot be substituted for cutbacks: (1) when long-life stockpiles are required, (2) for some emulsions when ambient temperatures fall below about $50^{o}F$, and (3) possibly when used as a penetrating prime coat. Others claim that these are not deterrents and that they have had success in using emulsions to replace cutbacks in all applications.

The price difference between the two types of liquefied asphalt was found to be not significant at this time.

Air Quality and Energy Conservation Benefits From Using Emulsions to Replace Asphalt Cutbacks in Certain Paving Operations

I. Purpose of Study

The purpose of this paper is to examine potential reductions in hydrocarbon emissions which may be achieved through substituting one kind of liquefied asphalt for another in certain paving operations. The paper reviews (1) the differences in asphalts liquefied with petroleum distillates (cutback asphalts), and (2) asphalts liquefied using water and an emulsifying agent (emulsified asphalts). Amounts of reactive hydrocarbons emitted when using cutback asphalts are discussed, as well as the substitutability of emulsified asphalts in place of cutback asphalts. Energy conservation considerations are presented, and the results of an eight-state telephone survey of highway paving practices are summarized.

II. Asphalt Paving - General

Asphalt is a by-product of petroleum distillation (natural or man-made) which man has put to use in many different ways. In ancient times he used it in its natural form to caulk boats and ships, as mortar in masonry construction, and as a cement for mending stone tools. Now we use it for roofing, weatherproofing, floor tile, insulating materials,

molded electrical equipment, papers, shingles, coatings, and many other applications. One of its better known uses is for pavements. Because of its durability and weather resistant qualities we use it in many different paving applications. These pavement uses can range from a thin layer sprayed on a dirt road to keep down dust, to a heavy duty pavement of thick layers of asphalt mixed with aggregate (crushed rock, gravel, slag or sand) placed on a well prepared base and designed to carry heavy traffic. In between these two extremes, asphalt pavement may be of a wide variety of thicknesses and strengths, depending on the traffic it will have to carry.[1]

Asphalt surfaces and pavements are composed of compacted aggregate and asphalt. Aggregate materials are produced from rock quarries as manufactured stone or obtained from natural gravel or soil deposits. Metal ore refining processes produce artificial aggregates as a by-product. The aggregate performs three functions. It transmits the load from the surface to the base course, takes the abrasive wear of traffic, and provides a nonskid surface. The asphalt binder holds the aggregate together, preventing displacement and loss of aggregate, and provides a waterproof cover for the base. Asphalts take the form of asphalt cement (the residue of the distillation of crude oils), and liquefied asphalts. Liquefied asphalts are: (1) asphalt cutbacks (asphalt cement thinned, or "cut back" with volatile petroleum distillates such as naphtha, kerosene etc.), and (2) asphalt emulsions (nonflammable liquid, produced by combining asphalt and water with an emulsifying agent such as soap). Asphalt cement, which is semi-solid, must be heated to convert it to a useable liquid. Asphalt cutbacks and asphalt emulsions are produced

in a wide variety of types and grades related to intended use, curing time and structural design requirements. Some of the uses are defined in Appendix A.

Emulsified asphalts are used widely in the construction and maintenance of pavements ranging from high-traffic-volume highways and airports to low-volume rural roads and city streets. Although emulsions have been available since 1903 and used extensively since the 1930s, recent energy and environmental problems have focused attention on increased use of these materials. The use of emulsions can reduce energy requirements by reducing or eliminating petroleum distillates that are used in liquefied asphalts and by lowering heating requirements, especially in heating aggregates to dry them. The elimination of petroleum distillates also reduces air pollution by eliminating emissions of hydrocarbons evaporated during the curing process.

Asphalt paving is a seasonal operation, with cold temperatures and rainy weather severely limiting construction and maintenance operations. Winter-time paving is usually limited to emergency repairs, although some states have claimed good results even during periods of low air temperature. Some emulsified asphalts (nonionic and anionic) usually are not used when rain is anticipated or when air temperatures fall below 50°F. With cationic emulsions these deterrents are not critical since curing depends on the electrochemical action of the positively charged emulsion bonding with the negatively charged aggregate surface. Generally speaking, emulsified asphalt can substitute for cutbacks in almost any application. Some believe that emulsions are not good for priming purposes, others believe that proper soil preparation is the answer, and still

others question the very need for priming. Some states have had no success with long-term stockpiling (more than 3-4 weeks) while others, using heated tanks or using mixes with a relatively small amount of fuel oil included, have had excellent results in stockpiling for a year or more. The same construction equipment used for cutbacks can be used for emulsions. A moderate amount of training (one or two days) is recommended before first using emulsions. This training is readily available from members of the Asphalt Emulsion Manufacturers Association. Local policies which encourage the use of cutbacks are the only known institutional constraints that inhibit the use of emulsified asphalt. Appendix B presents more detail on the advantages and limitations of emulsified asphalts.

III. Previous Efforts to Encourage Emulsified Asphalt Use

Some of the organizations concerned with energy problems affecting the supply and use of asphalt road paving materials are: Department of Transportation (DOT), Federal Highway Administration (FHWA), Federal Energy Administration (FEA), U. S. Department of Agriculture (USDA) Forest Service, Environmental Protection Agency (EPA), Transportation Research Board (TRB), National Asphalt Pavement Association (NAPA), The Asphalt Institute (AI), Asphalt Emulsion Manufacturers Association (AEMA), American Society for Testing and Materials (ASTM), American Road Builders Association (ARBA), American Association of State Highway and Transportation Officials (AASHTO), and state and local highway agencies.

In December 1973 and again in January 1974, FHWA issued notices concerning fuel conservation in federally funded highway construction programs. (Appendix B & D contain copies of these two notices.)

These notices encouraged state officials to minimize the use of cutback asphalts by substituting emulsions and to reduce mixing temperatures. They also provided guidelines on conserving fuel and presented analyses which demonstrated the large quantity of petroleum distillates which could be saved by substituting emulsified asphalts for cutbacks. FEA and EPA studies resulted in the conclusion that increasing fuel prices had already established a trend of increased use of emulsions. To accelerate this trend, FEA contracted with the National Research Council's Transportation Research Board to produce a synthesis report[2] on the use of asphalt emulsions for pavements. This report was widely publicized by DOT and various trade associations. FEA alone distributed 4,700 copies to city and county engineers in December 1975. In October 1975, EPA informed its regional offices by letter of the advantages of emulsified asphalts over cutbacks and advised the regional offices to encourage the use of emulsions to save energy and reduce emissions of hydrocarbons.

Other agencies and organizations have been at work on the problem. For example, NAPA[3] has published a paper on energy conservation in highway paving, AEMA has been making extensive efforts throughout its membership to encourage the use of asphalt emulsions, and USDA Forest Service has published a report on its experience in using asphalt emulsions, as has the Navajo Area Bureau of Indian Affairs.[4] However, only very recently has there been any indication of a trend toward switching from cutbacks to emulsions.

IV. Air Quality Considerations

The volatiles in cutback asphalts release hydrocarbons into the atmosphere in amounts that vary according to the type of cutback.

Cutback asphalts fall into three broad categories: Slow Cure (SC) (sometimes referred to as Road Oil), Medium Cure (MC) and Rapid Cure (RC). Cutback content averages 35% diluents (hydrocarbons).[3] SCs are a fairly heavy residual oil in the Bunker C range. MCs are diluted with a kerosene-type solvent. RCs are diluted with a heavy naphtha or a gasoline-type solvent. For the purposes of calculating hydrocarbon emissions estimates in this document the average value of 35% hydrocarbons is used to demonstrate order of magnitude.

Table 1 is a summary of estimated hydrocarbon emissions resulting from the use of cutback asphalts for paving purposes.[5] The emission calculations are based on the 35% volatiles contained in the cutbacks and on the following estimated evaporation amounts: SC - 20%-30% evaporated (average: 25%), MC - 60%-80% evaporated (average 70%), and RC - 70%-90% evaporated (average: 80%). Results of evaporation rate testing now being done for EPA by Midwest Research Institute form the basis for these estimated evaporation amounts. Most of the loss is believed to take place early during paving operations. Continuing amounts are lost to the atmosphere as time goes by but at an ever decreasing rate.

Table 1. SUMMARY OF NATIONAL HYDROCARBON EMISSION ESTIMATES FROM THE USE OF CUTBACK ASPHALT PAVING PRODUCTS

	Volatiles, tons/year	HC emissions, tons/year
1971	1,916,857	1,146,915
1972	1,830,724	1,112,932
1973	1,975,451	1,210,233
1974	1,613,454	973,516
1975	1,434,895	886,348

It is important to remember that paving operations are seasonal and that the paving season occurs during the warm weather months when formation of oxidants from photochemical synthesis of hydrocarbon emissions is most prevalent. Attempting to arrive at specific answers to questions about photochemical reactivity of the hydrocarbons emitted by cutbacks is complicated by the fact that there are so many cutbacks of varying chemical compositions. The situation is further complicated by the variables of solar radiation, cloud cover, air mass stagnation, hydrocarbon concentrations, and oxidant formation. However, cutbacks can be classified as moderately to highly reactive as far as oxidant formation is concerned.

Emulsified asphalts, on the other hand, consist of asphalt liquefied with water containing an emulsifier. Emulsions are relatively pollution-free with few volatiles to evaporate into the atmosphere.[6] FHWA has pointed out that there may be some distillates in some formulations of emulsified asphalt.

Table 2 indicates the relationship of hydrocarbon emissions from cutback asphalts used in paving, to national hydrocarbon emissions. (Asphalt paving operations are not now included as a source of HC emissions in the national summary).

Table 2. HYDROCARBON EMISSIONS FROM CUTBACK ASPHALT AS A PERCENTAGE OF NATIONAL HC EMISSIONS

	Summary of national HC emissions, 10^6 tons/year	Relationship of cutback asphalt HC emissions to national HC emissions %
1971	33.3	3.4
1972	34.1	3.2
1973	34.0	3.5
1974	32.9	2.9
1975	30.9	2.8

Table 3 shows a breakdown of national hydrocarbon emissions for mobile and stationary sources and displays the emissions from cutbacks in context with the two other sources.

Table 3. U.S. HYDROCARBON EMISSIONS BY CATEGORY[7]
(10^6 tons/year)

	Mobile sources	Stationary sources	Cutback sources
1971	13.7	19.6	1.1
1972	14.0	20.1	1.1
1973	13.7	20.3	1.2
1974	12.5	20.4	1.0
1975	11.7	19.2	0.9

Appendix C contains additional detailed information: Table C-1 summarizes annual national sales of cutback asphalts for paving purposes from 1971 through 1975; Table C-2 displays by EPA Region and by State, sales of cutback asphalts and sales of emulsified asphalts in 1975; and Table C-3 displays by EPA Region and by State the statewide hydrocarbon emissions from the use of cutback asphalts, State total hydrocarbon emissions, and the percentage of State total emissions accounted for by the cutback asphalts.

It is further noted that some states experience frequent air mass stagnation and have oxidant air quality problems. Some of these states, e.g., Wisconsin, Indiana, Illinois, Ohio, Pennsylvania, Virginia and West Virginia, require regulatory control of HC emissions for attainment and maintenance of oxidant ambient air quality standards. Most of these states also have significant quantities of hydrocarbon emissions attributable to paving with cutback asphalts.

V. Energy Conservation Considerations

In 1975, 10,249,250 barrels of petroleum diluents were used to liquefy asphalt for road paving operations. This amount of cutback is equivalent to 464,906,000 gallons of gasoline, enough to fuel almost 558,000 automobiles for a single year in the United States. Rather than powering automobiles, airplanes, or industry, however, energy in the form of diluents was poured onto road surfaces, where some evaporated and some remains. The energy impact of using cutback asphalts is just as striking when viewed in terms of the energy expended per gallon of paving material. The total energy associated with manufacturing, processing, and laying one gallon of cutback asphalt is about 50,200 Btu. On the other hand, analysis of emulsified asphalts shows that about 98% of the petroleum diluents is replaced with water with the result that only about 2,830 Btu is associated with each gallon of paving material. The components of these energy costs are described in Appendix D.

VI. Eight-State Survey of Paving Practices and Economic Considerations

State highway maintenance divisions in eight states were contacted for information, opinions, and experiences regarding the use of emulsified asphalt paving materials. The states selected for this survey were the larger users of asphalt. Since each state is responsible for some fraction (which may differ for each state) of the roads within its boundaries, this survey addresses only those asphalt paving operations for which the state is directly responsible.

In general, the survey showed that there has been an increased use of emulsified asphalts. This increased use, which varies with each

state contacted, has been brought about primarily through fuel conservation measures and economic considerations. Relatively little consideration is given to HC emission from paving operations. For example, in Allegheny County, Pa., the Pennsylvania DOT uses emulsified asphalts almost exclusively for county road paving operations because of conservation and economics. In areas where such considerations do not exist, the choice of emulsified asphalt or cutback asphalt depends largely upon user preference as well as experience in specific materials and suppliers.

Individual responses ranged from general acceptance of emulsified asphalts for paving to indifference and skepticism about emulsions. Pennsylvania has changed from 30% emulsions/70% cutbacks in 1973 to 70% emulsions/30% cutbacks today. New York State uses 97% emulsions/ 3% cutbacks.

New York and Pennsylvania have initiated training programs to instruct their personnel and contractor personnel in the correct use of emulsions.

Appendix E further describes the eight-state survey.

VII. Summary and Conclusions

The air quality and energy conservation aspects of the use of liquefied asphalt for paving operations have been analyzed to determine the potentials for energy savings and reduced emissions. Cutback asphalts are liquefied with hydrocarbon distillates such as kerosene or naphtha; these reactive hydrocarbons are emitted during the curing process. Emulsified asphalts use water and an emulsifying agent for liquefaction; virtually no pollutants are emitted during the curing of emulsions. Some

suppliers of emulsified asphalt include small amounts of distillates in their emulsions. In such cases the amount of hydrocarbons emitted would be a function of the amount of distillates used.

Overall, more than 10,000,000 barrels of distillates are used annually for paving purposes. Most of this is evaporated into the atmosphere; the remainder is retained in the pavement. Use of emulsions would save much of those 10,000,000 barrels of distillates for use as or conversion to fuels.

In some states the curing of cutback asphalts accounted for a significant amount of the state's total annual hydrocarbon emissions. This problem is made more serious by the fact that asphalt paving operations take place primarily during warm weather when oxidant formation from the photochemical synthesis of hydrocarbon emissions is most likely. Reduced use of cutback asphalts could decrease materially the oxidant problem in these states.

It is anticipated that a minimal amount of cutback asphalt will continue to be used at air temperatures lower than $50^{o}F$ and for dusty surfaces. Also, some cutbacks will be used where portable plants are not available, because the stockpile life of emulsions is a problem for some operators. Other concerns (discussed in Appendix B), can usually be met through good management.

Significant energy savings and air quality improvements can be realized from the increased use of emulsified asphalts.

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APPENDIX A

COMMONLY USED TERMS ASSOCIATED WITH ASPHALT PAVING OPERATIONS

Appendix A

Commonly Used Terms Associated with Asphalt Paving Operations

1. Crack Filler - Asphalt used to fill and seal cracks in existing pavements.
2. Dust Palliative - A light application of liquefied asphalt (cutback or emulsified asphalt) for the express purpose of controlling loose dust.
3. Maintenance Mix - A mixture of asphalt and mineral aggregate for patching holes, depressions, and distressed areas in existing pavements. These mixes are suitable for relatively small spot application, hot or at ambient temperature, using hand-laying and compaction techniques. This includes mixes for immediate use or for stockpiling for future use.
4. Penetration Macadam - Pavement construction using essentially one-size coarse aggregate that is penetrated in place by an application of asphalt binder. The asphalt application may be followed by an application of finer aggregate to reduce the void space.
5. Plant Mix, Cold Laid - A mixture of liquefied asphalt (cutback or emulsified asphalt) and mineral aggregate prepared in a central bituminous mixing plant and spread and compacted at the job site when the mixture is at or near ambient temperature.
6. Plant Mix, Hot Mix - Hot Laid - A mixture of paving asphalt and mineral aggregate usually prepared in a conventional hot-mix plant or dryer-drum mixer at a temperature of about 250°F and spread and compacted at the job site at a temperature above 200°F.

7. Prime Coat - An application of asphalt to an absorptive surface to penetrate and bind the aggregate surface and promote adhesion between it and the new superimposed construction.
8. Road Mix (Mix-In-Place) and Travel Plant Mix - A procedure by which the asphalt and mineral aggregate are mixed on the job site by means of travel mixers, motor graders, or other special road-mixing equipment.
9. Surface Treatment - An asphalt surface that results from one or more successive alternate applications of asphalt binder and cover aggregate to a prepared consolidated gravel, crushed stone, waterbound macadam, earth, stabilized soil, or similar base. Multiple application of asphalt and mineral aggregates may be used.
10. Seal Coat - An asphalt surface that results from one or more successive alternate applications of asphalt binder and cover aggregate to an existing paved surface.
11. Slurry Seal - A uniform application of a mixture of emulsified asphalt, fine aggregate, mineral filler, and water to an existing pavement. Single or multiple applications may be used.
12. Tack Coat - An application of asphalt applied to an existing surface to provide a bond between new surfacing and existing surface and to eliminate slippage planes where the new and existing surfaces meet.

APPENDIX B

PROS AND CONS - EMULSIFIED ASPHALTS

Appendix B

Pros and Cons - Emulsified Asphalts

In any comparison of alternate methods for accomplishing a given job there is usually a concern for the advantages and disadvantages of one method relative to another. In the evaluation of emulsified asphalts versus cutback asphalts, such concerns were raised and have been considered. Reduced hydrocarbon emissions and fuel conservation have been cited as advantages to be expected from the use of emulsified asphalts instead of cutback asphalts. The reduction in emissions and the fuel savings are significant. Cost comparisons are generally favorable to emulsified asphalts but there are specific instances where the cost differential is negligibly small. While the foregoing suggests that the large-scale use of emulsified asphalts should be encouraged, there are a number of reasons given by some users which prevent a complete switchover to emulsified asphalts. These include: (1) Varying experiences with stockpile life. Use of portable mixing plants, heated tanks, and inclusion of a small amount of fuel oil should overcome this objection. (2) Possible washout in a heavy rain. Cutbacks are also susceptible to washout. (3) "It's not like buying an 'off-the-shelf' item." Cooperation between the contractor, aggregate supplier, and emulsion supplier should result in the proper selection of an emulsified asphalt. (4) Miscellaneous reasons which can be met through the implementation of a training program to instruct contractors and operators in the proper use of emulsified asphalts. Some comments by FHWA follow:

"In some States, maintenance materials may be purchased on annual contracts. This may create ideal conditions for the use of emulsions since the available expertise of the emulsion manufacturer can be utilized to insure a satisfactory product by adjusting the emulsion formulation to suit the aggregates, designing the mixture and training personnel. In the competitive bidding situation for construction projects this may not be the case. Traditionally, State's material sections have either designed the bituminous mixtures or verified the contractor's submitted mix design for adequacy to the intended purpose. A number of the States have had little or no experience in the design of asphalt emulsion mixtures and currently there are no nationally recognized standard procedures for the laboratory design of these mixtures as there is for hot asphaltic concrete or cutback asphalt mixes. A large research effort is necessary in this area."

"It can be safely said that all of the State highway agencies are aware of and concerned with the needs for energy conservation and protection of the environment. The slower than desired trend by some of these agencies toward total substitution of emulsions for cutbacks can in part be attributed to the following factors.

1. Lack of nationally accepted standard laboratory design procedures for asphalt emulsion mixtures.* A number of design methods have been developed, mostly by members of the emulsion manufacturing industry.

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*Authors' Note: Similarly, there are only regionally accepted prodecures for cutbacks. There are no nationally accepted precision statements available on any design procedure for hot mixes and cutbacks.

None of these have been endorsed by the standardizing associations AASHTO or ASTM. The availability of a recognized objective reproducible laboratory design procedure for use by the highway agencies is considered a necessity in the effort to foster greater usage of asphalt emulsions.

2. Lack of reliable data on the structural worth of the asphalt emulsion mix. The pavement designer needs this information in the development of the structural section for a project. The general use of emulsions in the past has not been conducive to obtaining this type of data.

3. The tight money conditions that most State highway agencies have experienced in the past 3 years. This has not enhanced the climate for highway agencies to more or less experiment with a new product particularly when there is no price advantage. In response to item 1 above, the FHWA's Office of Research and Development has underway an in-house effort to develop a laboratory method of asphalt emulsion mix design. However, the allocation of necessary manpower and financial resources has been somewhat limited because of competing research requirements. That is not to say that we believe the effort to be unwarranted, just that strictly from a highway point of view there are other, more urgent, research needs."

An FHWA Notice (January 1974) is attached.

U. S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

SUBJECT	FHWA NOTICE
Use of Emulsified Asphalts in Lieu of Cutback Asphalts in Highway Construction and Maintenance Operations	N 5080.5 January 17,1974

1. PURPOSE. To direct the attention of the Federal Highway Administration field offices, States, and local governments to overall fuel savings possible using emulsion asphalts in lieu of cutback asphalts for highway construction and maintenance operations.

2. BACKGROUND.

   a. The national energy crisis relative to fuel and petroleum distillate shortages, as well as ecological problems with atmospheric contamination, necessitates consideration of an alternative for cutback asphalt use in highway construction and maintenance work.

      Cutback asphalts require heating before application and incorporate petroleum products in short supply that almost entirely evaporate into the atmosphere. The fuel and cutback solvents could be used for higher priority items and, at the same time, would lessen the pollution problems associated with bituminous work.

   b. A U.S. Bureau of Mines tabulation for petroleum asphalts consumed in the United States in 1972 relative to highway construction and maintenance is as follows:

      Asphalt Cement and Fluxes ..... 24,725,001 tons
      Emulsified Asphalts ..... 2,535,833 tons
      Cutback Asphalts ..... 3,860,094 tons

      Assume 1-ton of cutback asphalt = 240 gallons
      3,860,094 tons x 240 gallons/T = 926,400,000 gallons of cutback asphalt used.

      The average cutback asphalt is composed of one-third solvent and two-thirds asphalt, therefore, one-third solvents (kerosene or naptha) of 926,400,000 gallons = 309,000,000 gallons of

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petroleum products in the critical supply category which can possibly be saved by use of emulsified asphalts in lieu of cutback asphalts.

c. Emulsified asphalts are mixtures in which minute globules of asphalt are dispersed in water or aqueous solutions by means of an emulsifier to assure coating of aggregates. Emulsifiers include soap of fatty or resinous acids, glue, and gelatin. Use of emulsified asphalts is not a new concept since they have been used in varying degrees by State and local construction and maintenance agencies for a number of years. The magazine titled "Rural and Urban Roads" published three reports on how the States were using emulsions. Part I of the report was published in February 1972, Part II in April 1972, and Part III in June 1972. Over 20 States detailed the scope of their use of emulsions. An overall State summary was included in Part I and showed that emulsions were used as follows:

Subbases	= 8 States
Base Mixes	= 15 States
Cold Mix Surfacing	= 10 States
Shoulders	= 20 States
Primes	= 30 States
Sealcoats for Surface Treatments	= 38 States
Surface Treatments	= 38 States
Slurry Treatments	= 24 States
Cold or Hot Patching	= 15 States

A recent Federal Highway Administration survey has revealed that most of the States are presently using emulsified asphalts in maintenance operations where in many cases cutback asphalts had formerly been used.

d. Some advantages in using emulsion asphalts rather than cutback asphalts are:

1. Reduced atmospheric pollution problems.
2. Emulsions penetrate and seal cracks in existing surfaces during chip seal procedures prior to "breaking." The term "breaking" as applied to emulsified asphalts, refers to the condition where separation of water and asphalt occurs.

3. Emulsions can be applied at lower temperatures since little or no external heat is required. This presents a greater safety factor since none or a minimum of petroleum distillate is present.
4. Setting characteristics of emulsions can be varied over a wider range than cutbacks. Setting is not dependent on the solvent and this gives desirable properties for tack coats, slurry seals, and surface treatments.
5. Emulsions have the ability to coat wet surfaces of aggregates.
6. Potential cost savings whenever emulsions are used.

e. Reference specifications for use of emulsion asphalts are:

Standard Specification for Emulsified Asphalt - AASHO M140 (ASTM D977) (Anionic)

Standard Specifications for Cationic Emulsion Asphalt - AASHO M208 (ASTM D2397)

3. ACTION.

a. Since the situation regarding fuel shortages appears likely to become more acute as time goes on, it is directed that the Federal Highway Administration field offices strongly urge the States and local governments to use emulsified asphalts in lieu of cutback asphalts whenever feasible. This is especially important since serious delays in highway construction may be encountered where cutback asphalts having petroleum products in short supply are specified. Areas in which emulsions have been used are:

1. Soil Stabilization.
2. Tack Coats.
3. Prime Coats (Except where special penetration is needed).
4. Sub-Bases.
5. Bases.
6. Intermediate Pavement Layers.
7. Surface Treatments.
8. Slurry Seals.
9. Shoulder Treatments.
10. Curing Seals for Cement-Treated Bases.
11. Cold-Patching.
12. Mulching Tiedown.
13. Penetration Macadam.
14. Dust Palliatives.

b. There will be a need to evaluate and adjust current specifications in order to provide types and grades of emulsions as direct substitutes for existing cutback materials. Modification of existing contracts to substitute emulsified asphalts for cutback asphalts is encouraged where feasible.

c. Emulsified asphalts have been used to some degree in lieu of conventional heated plant mixtures, principally in base courses. In some western States, experimental special open graded emulsified asphalt mixtures have been used successfully to construct full depth flexible pavements. Experimental project construction utilizing asphalt emulsion pavement mixtures are encouraged in order to learn more about thickness equivalencies and service performance of such mixtures. Where full depth open graded mixtures are used experimentally, special attention should be given to the quality of the subgrade and the provision of durable skid resistant surfaces. Aside from obvious advantages of reduced heating requirements and attendant pollution problems, there are indications of significant cost savings with the open graded asphalt emulsion pavement mixtures.

d. Although emulsified asphalts can be substituted for cutback asphalts in many situations as pointed out in this Notice, there will continue to be instances where cutback asphalts will be required for one reason or another. Even though emulsions can be used with aggregates which are not entirely dry, excessive moisture from rain or showers can result in complete loss of the work if the emulsified asphalt has not broken completely. The emulsified asphalts are more susceptible to problems during colder weather where stripping can occur because of the slower break. Proper mixing procedures are important because excessive mixing can cause stripping. Stockpiling of emulsified asphalt mixes for long periods should be avoided, as this has led to problems due to premature or partial breaking.

e. Attachment "A" contains a bibliography of some reports, papers, and articles regarding the use of emulsions in bases, surfaces, etc., in highway work. These publications contain data of a technical nature as well as sample specifications.

H. A. Lindberg
Associate Administrator for
Engineering and Traffic Operations

Attachment "A"

EMULSIONS

How the States Use Emulsions - Rural and Urban Roads, February, April, and June 1972 publications.

Bitumuls Base Treatment Manual - Chevron Asphalt Company - 555 Market Street, San Francisco, California 94120.

Design and Construction of Emulsified Asphalt Open-Graded Mixes and Overlays (March 17, 1972) - L. P. Coyne, Research Engineer, Chevron Asphalt Company.

Emulsified Asphalt Hot Mixes (November 1970) - J. Ferguson, Pounder Emulsions - 1474 Wall Street, Winnipeg 3, Manitoba.

Emulsified Asphalt for Better Paving - K. E. McConnaughay, Asphalt Plants and Processes - 426 Columbia Street, Lafayette, Indiana.

Thickness Equivalencies - Charles R. Foster, National Asphalt Pavement Association, 6715 Kenilworth Avenue, Riverdale, Maryland.

APPENDIX C

LIQUEFIED ASPHALT DATA: SALES, HYDROCARBON EMISSIONS ESTIMATES - NATIONAL AND STATE SUMMARIES

Appendix C

Liquefied Asphalt Data: Sales, Hydrocarbon Emissions Estimates - National and State Summaries

Table C-1 displays a summary of national sales of cutback asphalt for paving purposes. It is based on Bureau of Mines annual reports of asphalt sales for the years shown. The Bureau of Mines data are further broken down into the three categories of cutbacks based on an estimated usage ratio of 65% Medium Cure (MC) and 35% Rapid Cure (RC).

Table C-1 SUMMARY OF NATIONAL SALES OF CUTBACK ASPHALTS FOR PAVING (TONS/YEAR)

Year	Slow cure (Road Oils)	Medium cure	Rapid cure	Total
1971	1,543,091	2,557,868	1,375,775	5,476,734
1972	1,370,546	2,509,061	1,351,033	5,230,640
1973	1,424,000	2,743,095	1,477,051	5,644,146
1974	1,251,091	2,183,205	1,175,572	4,609,868
1975	991,455	2,020,359	1,087,886	4,099,700

Table C-2 Sales of Cutback Asphalt and Emulsified Asphalt in 1975, by EPA Region and State

EPA Region and State	Cutback Asphalt Sales (Includes Road Oils) (tons)	Emulsified Asphalt Sales (tons)
Region I		
Connecticut	20,355	2,340
Maine	23,702	16,742
Massachusetts	18,510	4,855
New Hampshire	22,982	12,994
Rhode Island	927	677
Vermont	321	299
Region II		
New Jersey	26,528	55,357
New York	103,435	156,755
Region III		
Delaware	1,168	1,746
Maryland + D.C.	42,411	62,122
Pennsylvania	143,096	57,369
Virginia	58,222	58,270
West Virginia	11,707	31,238
Region IV		
Alabama	45,138	51,829
Florida	46,387	26,753
Georgia	50,003	56,318
Mississippi	2,989	27,658
Kentucky	37,241	71,455
North Carolina	31,966	80,631
South Carolina	16,993	47,514
Tennessee	25,651	112,447
Region V		
Illinois	312,041	31,042
Minnesota	129,783	17,815
Michigan	39,305	24,441
Ohio	297,417	182,896
Indiana	80,805	162,636
Wisconsin	125,093	16,853

Region VI		
Arkansas	68,829	40,454
Louisiana	19,867	35,631
New Mexico	70,848	40,228
Oklahoma	390,836	7,372
Texas	189,648	131,079
Region VII		
Iowa	98,242	17,496
Kansas	121,111	38,427
Missouri	470,686	13,102
Nebraska	21,928	8,519
Region VIII		
Colorado	73,736	1,255
Montana	50,692	6,099
North Dakota	49,373	22,140
South Dakota	41,152	5,771
Utah	27,397	17,006
Wyoming	15,705	1,931
Region IX		
Arizona	152,121	100,987
California	236,685	136,802
Hawaii	5,220	- -
Nevada	47,183	6,828
Region X		
Alaska	7,416	5,370
Idaho	60,426	21,008
Oregon	25,417	58,074
Washington	141,066	57,246
Total	4,099,700	2,143,877

Table C-3
Cutback Asphalt Hydrocarbon Emissions Contribution
to State Total Hydrocarbon Emissions

EPA Region and State	Cutback Asphalt HC Emissions Total* and % of State HC Emissions (tons)		State Total HC Emissions ** (tons)
Region I			
Connecticut	5,227	2.3%	221,736
Maine	6,087	4.6%	125,390
Massachusetts	4,747	<1 %	520,930
New Hampshire	5,902	6.3%	88,366
Rhode Island	238	<1 %	85,283
Vermont	82	<1 %	41,372
Region II			
New Jersey	6,812	1.1%	639,325
New York	26,223	2.3%	1,116,330
Region III			
Delaware	300	<1 %	64,813
Maryland & D.C.	10,891	2.5%	427,337
Pennsylvania	36,718	4.3%	811,992
Virginia	14,951	3.0%	483,501
West Virginia	2,985	2.6%	113,711
Region IV			
Alabama	9,997	1.4%	729,076
Florida	11,894	1.0%	1,140,776
Georgia	12,841	2.7%	467,461
Mississippi	662	<1 %	224,298
Kentucky	8,104	2.2%	352,382
North Carolina	8,209	1.5%	548,584
South Carolina	4,363	1.2%	360,971
Tennessee	5,582	1.4%	391,719
Region V			
Illinois	67,984	3.6%	1,831,465
Minnesota	28,244	6.9%	381,938
Michigan	8,554	1.0%	824,898
Ohio	66,090	5.6%	1,117,174
Indiana	17,585	2.8%	603,771
Wisconsin	21,710	3.6%	574,454

Region VI			
Arkansas	15,245	7.4%	189,896
Louisiana	4,400	< 1 %	1,228,769
New Mexico	15,525	9.8%	143,116
Oklahoma	86,850	18.1%	391,672
Texas	42,305	1.9%	2,211,509
Region VII			
Iowa	21,380	5.7%	353,844
Kansas	26,356	7.3%	336,756
Missouri	104,593	18.9%	448,299
Nebraska	4,772	1.3%	378,922
Region VIII			
Colorado	15,275	6.4%	224,797
Montana	10,494	5.0%	197,518
North Dakota	10,934	13.3%	71,522
South Dakota	8,956	9.5%	85,161
Utah	5,672	5.2%	103,047
Wyoming	3,251	4.6%	67,654
Region IX			
Arizona	27,436	10.2%	241,985
California	38,719	1.8%	2,115,039
Hawaii	889	<1 %	94,405
Nevada	8,088	13.1%	53,429
Region X			
Alaska	1,263	1.1%	109,370
Idaho	12,214	9.3%	118,532
Oregon	4,328	1.5%	290,495
Washington	24,011	6.7%	336,944

*Weighted average by state. See Table 1 narrative (Sect IV, p. 5)

**State total hydrocarbon emissions estimates are based upon latest available data on emission sources as presented in EPA-450/2-76-007, May 1976, "1973 National Emissions Report," National Emissions Data System (NEDS) of the Aerometric and Emissions Reporting System (AEROS). Asphalt paving operations were not included as a source.

APPENDIX D

ENERGY CONSERVATION CONSIDERATIONS

Appendix D

Energy Conservation Considerations

The energy associated with cutback asphalt can be compared with that associated with emulsified asphalt by considering their respective compositions, the attendant process energy, and the energy required for asphalt spray applications using an asphalt distributor. Since the petroleum distillates content of cutback asphalt varies from 20% to 50% of the total mixture, the energy associated with these asphalts spans a wide range. In order to strike one kind of comparison, consider cutback asphalt and emulsified asphalt, each with 65% asphalt. This is reasonable because this percentage is generally recommended for emulsified asphalts and the eight-state survey (Section VI and Appendix E) revealed that the amount of cutback asphalt (typically containing 60% - 70% asphalt) required for paving operations was about the same as for emulsified asphalts. About 2500 Btu is required to process a gallon of asphalt for paving* and to this is added the energy content of the cutback which, for a medium cure is about 135,000 Btu/gal. Thus, for one gallon of cutback asphalt with 65% asphalt and 35% cutback the energy represented therein is 2500 + .35 x 135,000 = 49,750 Btu. About 2050 Btu is required to obtain one gallon of emulsified asphalt, independent of emulsifier energy content.* According to ARMAK (leading manufacturer of emulsifiers) there is about 7500 Btu/lb associated with the production of emulsifiers. At about 0.084 lb emulsifier/gal (1%) an additional 630 Btu should be added to

* "Energy Requirements for Roadway Pavements," The Asphalt Institute (MISC-75-3) April 1975.

the 2050 Btu for each gallon of emulsified asphalt giving an intermediate total of 2680 Btu/gal.

Finally, the energy requirements for asphalt spray applications using an asphalt distributor amount to 444 Btu/gal for cutbacks and 144 Btu/gal for emulsions.* (An additional 300 Btu/gal is required to heat the cutback asphalt). Hence, the total energy associated with laying one gallon of cutback asphalt is about 50,200 Btu while the total energy associated with a gallon of emulsified asphalt is about 2830 Btu.

Each ton of petroleum diluent used in cutbacks is equivalent to about 300 gallons. The tons of volatile diluents displayed in Table C-1 convert to barrels (42 gals/bbl) as follows:

Table D-1 PETROLEUM DILUENTS USED TO LIQUEFY ASPHALT (ESTIMATED BBLS/YEAR)

1971	13,691,836
1972	13,076,600
1973	14,110,364
1974	11,524,671
1975	10,249,250

These petroleum diluents (fuels) were evaporated to the atmosphere or were retained in the asphalt pavement. In terms of energy content, the amount of gasoline equivalent to the 10,249,250 barrels of petroleum diluents used in 1975 for cutback asphalts is:

$$(10{,}249{,}250 \text{ bbl}) \times (42 \text{ gal/bbl}) \times \frac{135{,}000 \text{ Btu/gal diluent}}{125{,}000 \text{ Btu/gal gasoline}} =$$

464,906,000 gal gasoline

* "Asphalt Surface Treatments and Asphalt Penetration Macadam," The Asphalt Institute, Second Edition, November 1969, Manual Series No. 13 (MS-13)

For an annual mileage of 10,000 at 12 mpg this gasoline equivalent would fuel almost 558,000 automobiles for one year.

An FHWA Notice (December 1973) is attached.

U. S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

SUBJECT	FHWA NOTICE
Conservation of Fuel Federal-Aid Highway Construction Program Direct Federal Highway Construction Program	N 5080.2 December 6, 1973

1. PURPOSE

The purpose of this Notice is to set forth the Federal Highway Administration's position relative to the taking of immediate measures to conserve fuel on Federal-aid and direct Federal highway construction.

2. BACKGROUND

In view of the seriousness of the current fuel shortage and the likelihood of it worsening, it is imperative that all feasible steps be taken quickly to improve the efficiency of highway construction operations from the standpoint of fuel usage.

3. ACTION

Accordingly, FHWA field office personnel should meet with appropriate State officials to review and identify actions that could feasibly be taken under prevailing conditions to effect reduction in fuel usage on ongoing and future Federal-aid highway construction projects. FHWA direct Federal construction personnel should undertake a similar review of direct Federal highway projects. This review and action program should be initiated immediately. The Federal Highway Administration encourages and will accept design proposals and change orders that will effect fuel savings without undue sacrifice in the timeliness, quality, or cost of such construction.

Some suggested actions to consider are listed below:

a. Minimize the use of cut-back asphalts and road oils by substituting emulsions, and other bituminous products. The FHWA is presently preparing a detailed statement on this subject, which should be issued in the very near future. Present information indicates over 300,000,000 gallons per year of naphtha and kerosene could be saved by this substitution on construction and maintenance operations.

-more-

b. Reduce mixing temperatures for plant-mixed bituminous mixtures. Mixtures should be produced at the lowest temperature that will permit proper mixing, laydown, and compaction. Mixing temperatures should be based on the temperature-viscosity relationship at the particular type of grade of bituminous material being used. Data on this relationship should be required in chart form for each source. More detailed information can be found in "The Asphalt Handbook, Manual Series No. 4 (MS-4)" published by the Asphalt Institute. Utilization of mixtures produced at lower temperatures might require the use of insulated truck bodies and covers to retain adequate heat for laydown and compaction.

c. Use insulated forms instead of heated enclosures for cold weather concreting operations. Defer cold weather concreting except for critical items affecting the efficiency of other major operations or to avoid major delays in project completion.

d. Encourage carpooling by State, FHWA, and contractor personnel.

e. Use fewer but thicker lifts in bituminous pavements. Lifts in the 6-inch to 8-inch range have been successfully used in many areas, particularly in black base construction. However, consideration of thicker lifts should not be confined to bases but should also be considered for surface course layers.

f. Prohibit use of petroleum products to facilitate the burning of brush.

g. Assure that construction equipment is operated within manufacturer's recommended ranges.

h. Avoid the necessity to redo-grading by protecting it with adequate erosion control measures applied on a timely basis. Encourage the proper scheduling and performance of erosion control measures by relieving the contractor of responsibility for maintaining satisfactorily completed work.

i. Require the use of borrow and waste sites selected by the State to minimize fuel consumption. FHWA will find

-more-

mandatory use of such sites to be in the public interest if fuel savings would result.

j. Use mobile communication equipment to minimize project related travel.

k. Increase use of engineering studies to identify project conditions that would permit fuel saving construction features. For example, study the soils that will be used in embankment construction to determine the maximum permissible lift thickness(es). Where feasible, we would encourage the use of end result density specifications combined with test strip control to achieve thicker embankment lift construction.

Additional information relative to such highway program activities as design, selection of projects and possibly others, as they relate to conservation of fuel, is being developed and will be forthcoming.

R. R. Bartelsmeyer
Deputy Administrator

APPENDIX E

EIGHT-STATE SURVEY OF PAVING PRACTICES AND ECONOMIC CONSIDERATIONS

Appendix E

Eight-State Survey of Paving Practices and Economic Considerations

Eight state highway maintenance divisions were contacted for their opinions, facts, and experiences regarding the use of emulsified asphalt paving materials. The states selected were the larger users of asphalt. An initial contact with each state was made in order to establish an overview of their operations. A second contact was made to obtain more detailed information.

In discussions with the eight states it was found that there was an insignificant difference (overall) in the costs of the two types of asphalts at this time. Until three years ago the cutback asphalts were less expensive but the increase in oil prices has changed this picture.

The local picture may be influenced by varying economic considerations. However, the availability of light diluents from a nearby (and older) refinery could make cutbacks very attractive. Newer refineries are able to recycle naphtha and similar light stock to turn out a more profitable product. When a nearby source of these light diluents is not available, the additional freight costs to deliver the material usually tips the scales in favor of emulsions.

A specific example is found in Waukesha County, Wisconsin.* The switch to emulsions was made to conserve energy in 1973. In 1976 the county used emulsions for resurfacing and realized about a 10% cost saving in materials: 36.92¢/gal. for cutback vs. 33.75¢/gal. for emulsions.

* Rural and Urban Roads, November 1976, article on page 26, "Water Based Emulsions Help County Save Cash on Seal Coats."

The following is an account of discussions with each highway maintenance division.

Illinois

Primary roads are usually paved with portland cement concrete. Maintenance operations and paving of secondary roads are under local (city or county) jurisdiction. The local agencies are being encouraged ("jawboned") to use emulsified asphalts. The state "Specification Book" now lists emulsions as a viable option. Cationic and High Float Emulsions (HFE) are preferred (for definitions see reference 2). Stockpile life is no problem. There is almost no cost differential. Most user problems are expected to be resolved as more plants come into operation. Also, the expanded use of "porta-pugs" (portable on-site mixing equipment) should benefit pre-mix emulsions.

Paving with emulsions is not done after September 30. Under favorable conditions (3 consecutive preceding days with maximum temperatures over $60^{o}F$ in the shade and a night time minimum of $40^{o}F$ or higher) emulsified asphalts can be used until October 31. Use of emulsions is resumed in the spring when these temperature ranges are obtained.

Missouri

Until 3 or 4 years ago cutback asphalt was used exclusively. Today, emulsions are satisfactory for tack coats. Emulsions are generally unsatisfactory for road surfaces. The emulsified asphalt industry in Missouri is in its infancy and has not been able to live up to its claims.

Problems include emulsions break-up and non-adherence to aggregate resulting in rough surface. Procurement of emulsion asphalt is not like buying an off-the-shelf item. The emulsifying agent and proportions must

be tailored to the available aggregate the particular job. Their most successful emulsions use 4-10% cutback.

Most of the paving work is done under contract.

Pennsylvania

The Department of Transportation has its own environmental section which maintains liaison with the state Department of Environmental Resources.

The expanded use of emulsified asphalts was initiated as a fuel and cost conservation measure about three years ago. DOT has continued to use emulsions because they expect the cost of petroleum diluents to increase further. Pennsylvania is directly responsible for and controls much of its highway system (as do Virginia, North Carolina, and Texas), i.e., 44,000 miles of the 104,000 miles of roads in the state. The Pennsylvania DOT is under annual contracts with asphalt suppliers and hence control the type of asphalt to used on a given job.

About ten years ago emulsified asphalts were used for the first time. Three years ago usage was 30% emulsions. Today, it is 70% emulsions. No further increase is expected. The state is committed to emulsions and has directed its districts accordingly. One-day training programs have been set up for administrators as well as operators.

Hot-mix will be used for primary roads for some time because suppliers have considerable investment in plants and equipment.

A design procedure for Seal Coats (Surface Treatments) is available. Special mixes such as cold patch material requires stockpiling. All operations require strict quality control. Furthermore, mixes cannot be stockpiled in excess of a depth of 4 feet. Pennsylvania also uses travel-mix plants to prepare the emulsion on the job site.

Emulsions are used for recycling pavements. Cutbacks are still used for dust control.

Ohio

The increased use of emulsions is being encouraged. The state cannot, however, mandate to the local governments. At present there is an insignificant price differential but the cost of cutback asphalt is expected to increase.

Oklahoma

Emulsified asphalts are used for seal coats and slurry seals - about 10-15% more emulsified asphalt is required than cutback asphalt for a given surfacing requirement. Emulsions are not used for surface paving. There is an insignificant price differential today. Emulsion costs are expected to decrease but a trend to increased use of emulsions is not foreseen.

Texas

The state is trying to increase use of emulsions as a result of energy conservation efforts and financial conditions. Overall they find an economic advantage in the use of emulsions. Emulsions are not used for heavy traffic applications or where roads must be opened immediately after re-surfacing. Stockpile life for emulsions is about one month.

There are 25 Districts in Texas and each District Engineer is responsible for maintenance. Attitudes are important - some users have been using emulsions with success for years while others are unalterably opposed to it.

New York

In 1976, 97% of liquid asphalts used were emulsions; 3% were cutbacks. New York state has an educational program to instruct its personnel in the correct use of emulsions and recommends and stresses the advantages of emulsions over cutbacks. In 1977 the use of cutbacks will be restricted to pavement repairs only. The State knows that emulsions are actually being used in paving operations by inspecting and testing material for acceptance and adherence to specifications. They have experienced no stockpile problems. They feel that four weeks is a good average for stockpile life and generally use the material within a four week period. Some material has been stockpiled for longer periods with no problems. The foregoing information pertains only to the use of emulsions by the New York State Department of Transportation and does not include counties and municipalities within the state.

California

California State Department of Transportation uses cutbacks as the primary liquid asphalt. The emulsion that is used is mainly for seal coats. They have no prejudice against emulsions per se, but they stockpile for the whole winter, particularly for the remote areas in the northern part of the state, and emulsified asphalt stockpiles will not last more than a few weeks before they set up and become unusable. The cost differential between emulsions and cutbacks is negligible. Paving operations are in compliance with environmental requirements.

Although not a part of the eight-state survey, a discussion with the Southern California Air Pollution Control District, Metropolitan Zone (formerly L.A. District) is believed pertinent. Cutbacks are

forbidden to be used in that District under the Volatiles Rules, Rule 442 (Usage of Solvents) and Rule 443 (Labeling of Solvents). These rules are formerly known as Rule 66.

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General Services Division (MD-28)
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